Synthesis of silicon carbide nanoparticles in a microwave

Jean van Laar

In recent years, there has been a flood of scientific papers on the synthesis, processing and applications of the new – yet old – material called silicon carbide (SiC). This specific combination of silicon and carbon has been known since 1824, when it was first synthesised by Jöns Jacob Berzelius. Since then, the popularity of SiC has periodically varied. As modern technology developed, however, so did interest in SiC. The reason for this is the gradual discovery of its physical properties that are ideal for high-power, high-frequency and high-temperature applications.

Recently, the focus has shifted towards the nanoscale of this incredible substance. SiC nanoparticles exhibit properties different from the bulk material, encouraging the creation of new materials. Many different synthesis methods for the creation of SiC nanoparticles have been studied, for example, carbothermic reduction, pulsed-laser deposition and sol-gel processes. Each of these methods presents certain advantages. Microwave-induced plasma synthesis has now stirred the interest of a few researchers at the University of Pretoria.

Plasma, often called the fourth state of matter, is by far the most common form of matter in the universe (if dark matter is excluded). Plasma is defined as an ionised gas that displays collective behaviour. The term “ionised” implies that some of the electrons are not bound to an atom or a molecule, but move freely among such atoms or molecules. These electrons couple with the applied oscillating electric field, called the microwave field, and undergo impacts or interactions converting atoms or molecules into positively charged molecular and atomic ions and/or fragments. There are other techniques, such as radio frequency induction and direct current arcs, to induce plasma. Each technique uses different physical mechanisms and provides different operating conditions.

In a joint project with the Nuclear Energy Corporation of South Africa (Necsa), the departments of Chemical Engineering, and Mechanical and Aeronautical Engineering at the University of Pretoria have successfully synthesised SiC nanoparticles in a microwave plasma. With the use of methyl trichlorosilane as an organic precursor and argon as the carrier and ionising gas, it was possible to create ideal conditions for the conversion of the precursor to SiC nanoparticles. A typical product is shown in the image of the scanning electron microscope on the opposite page. In situ agglomeration of the particles has been a problematic hurdle to overcome, along with the challenge of mechanically separating the particles at nanoscale.

SiC research will continue over the next few years in cooperation with Necsa, and it will focus on the immobilisation of radioactive waste. SiC is already used in tristructural-isotropic (TRISO) fuel particles used in high-temperature reactors (HTRs) via thermal chemical vapour deposition. Furthermore, SiC shows promise as a replacement for the zirconium alloy tubes in the fuel elements of the current generation of water-cooled reactors. The use of plasma technology presents many advantages, but has its challenges. For example, the technology can be adjusted to yield either gas phase particulates or strongly adhesive coatings.

Scientists and engineers are excited to see what the future holds for this interesting and fast-paced field.

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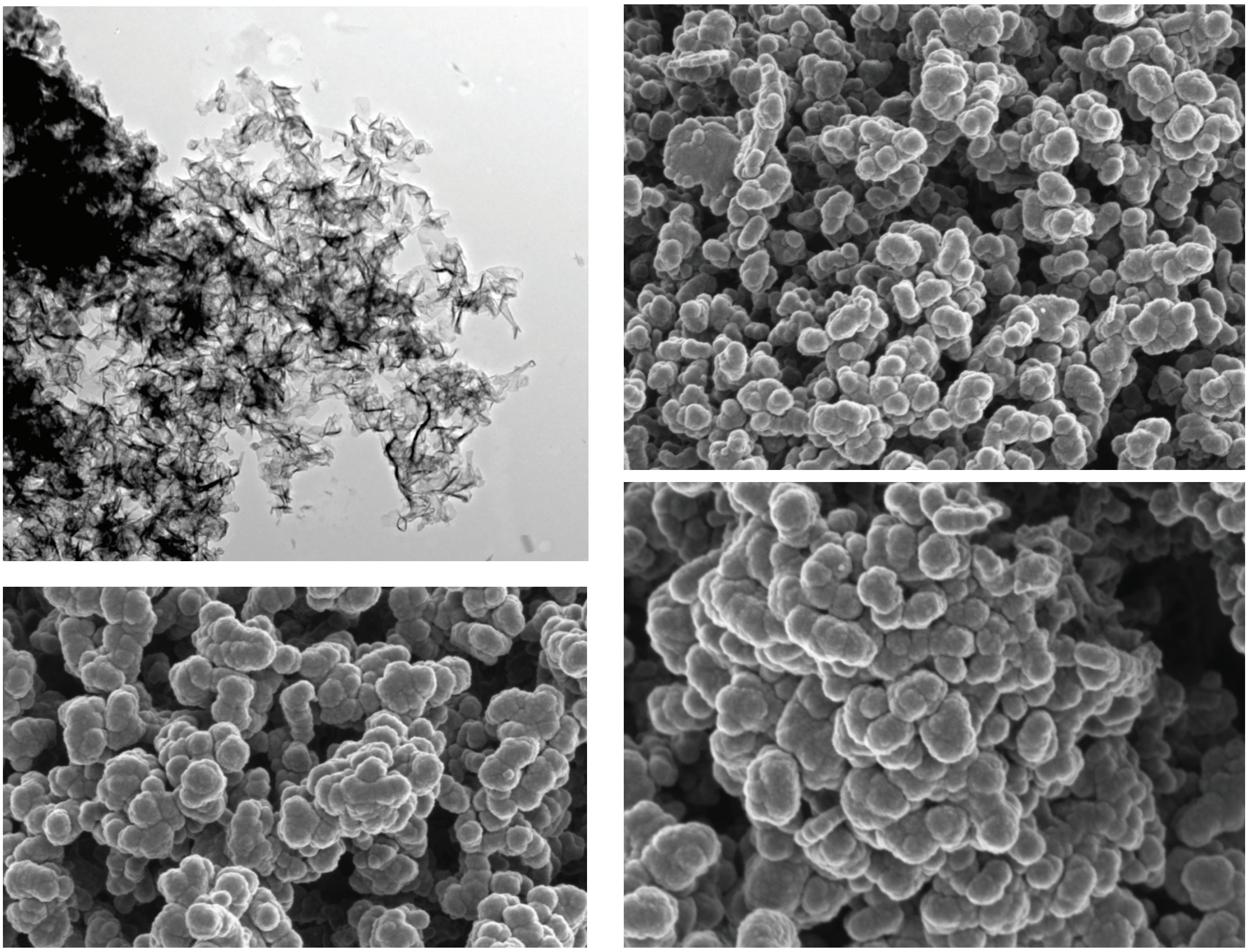
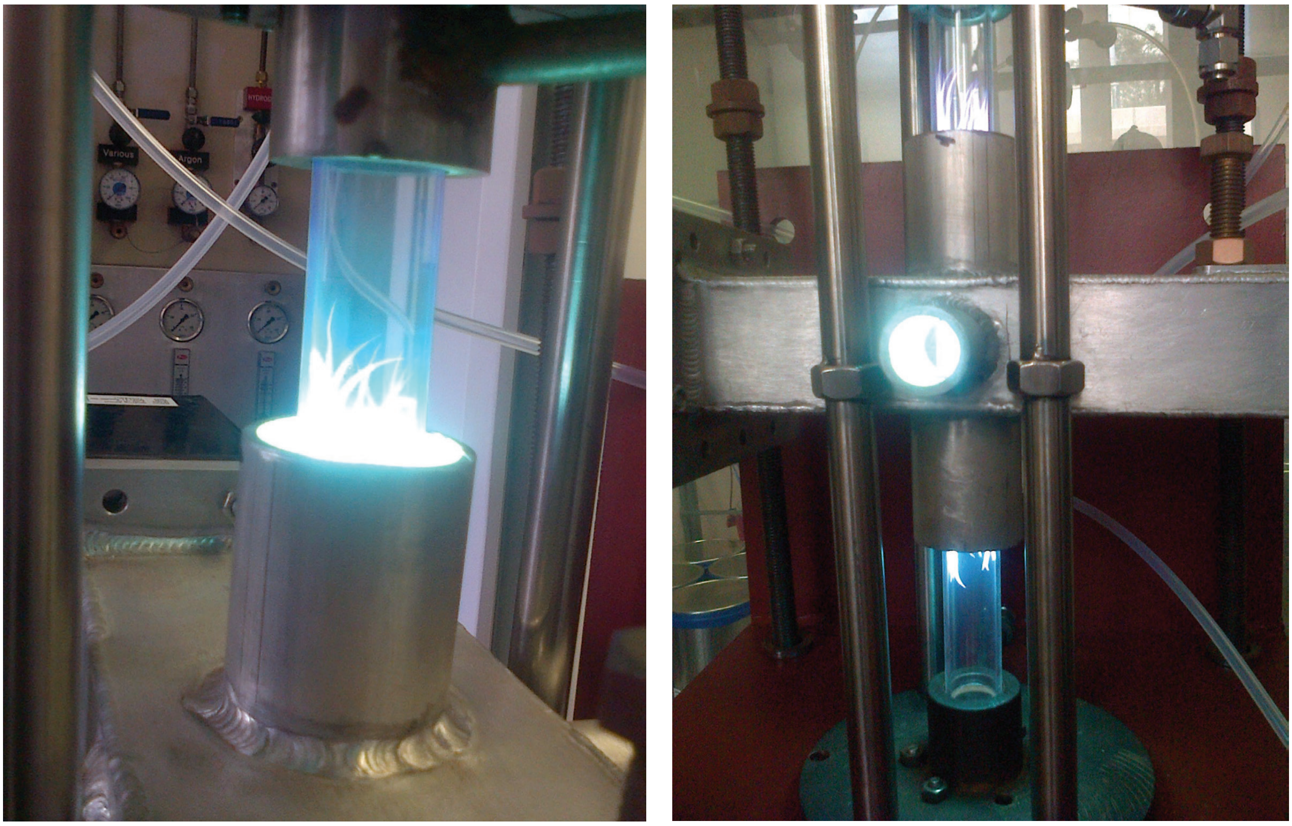


A typical product is shown in the image of the scanning electron microscope above.



Microwave-induced plasma and instruments.